Network Systems Science & Advanced Computing

Biocomplexity Institute & Initiative

University of Virginia

Estimation of COVID-19 Impact in Virginia

August 19th, 2020

(data current to August 18th)

Biocomplexity Institute Technical report: TR 2020-100

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biocomplexity.virginia.edu

About Us

- Biocomplexity Institute at the University of Virginia
  - Using big data and simulations to understand massively interactive systems and solve societal problems
- Over 20 years of crafting and analyzing infectious disease models
  - Pandemic response for Influenza, Ebola, Zika, and others

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Overview

- **Goal**: Understand impact of COVID-19 mitigations in Virginia
- **Approach:**
  - Calibrate explanatory mechanistic model to observed cases
  - Project infections through October
  - Consider a range of possible mitigation effects in "what-if" scenarios
- **Outcomes:**
  - Ill, Confirmed, Hospitalized, ICU, Ventilated, Death
  - Geographic spread over time, case counts, healthcare burdens

Key Takeaways

Projecting future cases precisely is impossible and unnecessary.
Even without perfect projections, we can confidently draw conclusions:

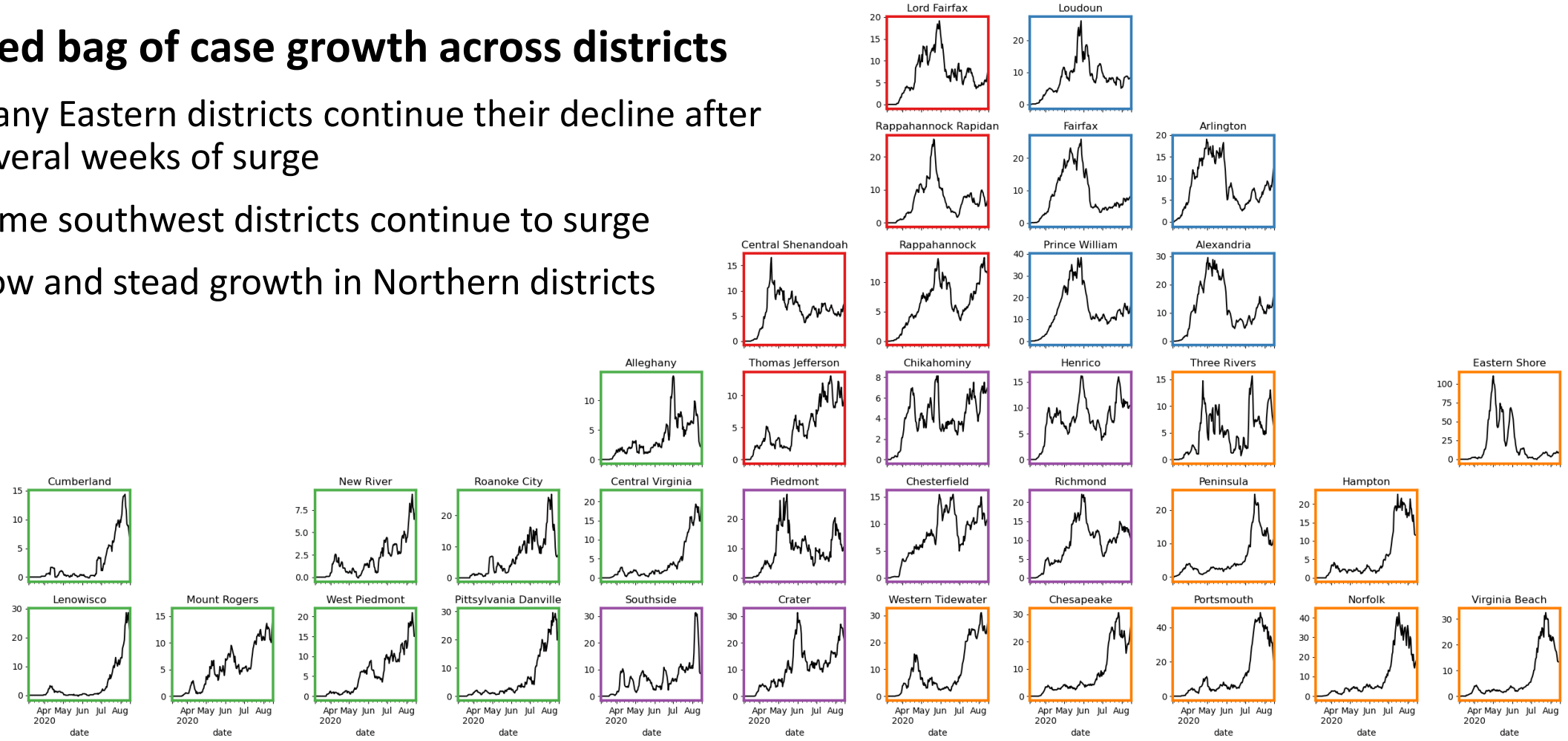
- **Surges are ending and slowing though incidence is high.**
- Mixed trends across the commonwealth: surges, steady growth, slowed surges, and declines
- Projections show increasing incidence in short-term
- Recent model updates:
  - Adaptive Fitting projection, projection selection phased out
  - Seasonal effects scenarios for planning for end of summer changes
  - Extend projection horizon to Nov 1
- The situation is changing rapidly. Models will be updated regularly.

Situation Assessment

Case Rate (per 100k) by VDH District

Mixed bag of case growth across districts

- Many Eastern districts continue their decline after several weeks of surge
- Some southwest districts continue to surge
- Slow and stead growth in Northern districts



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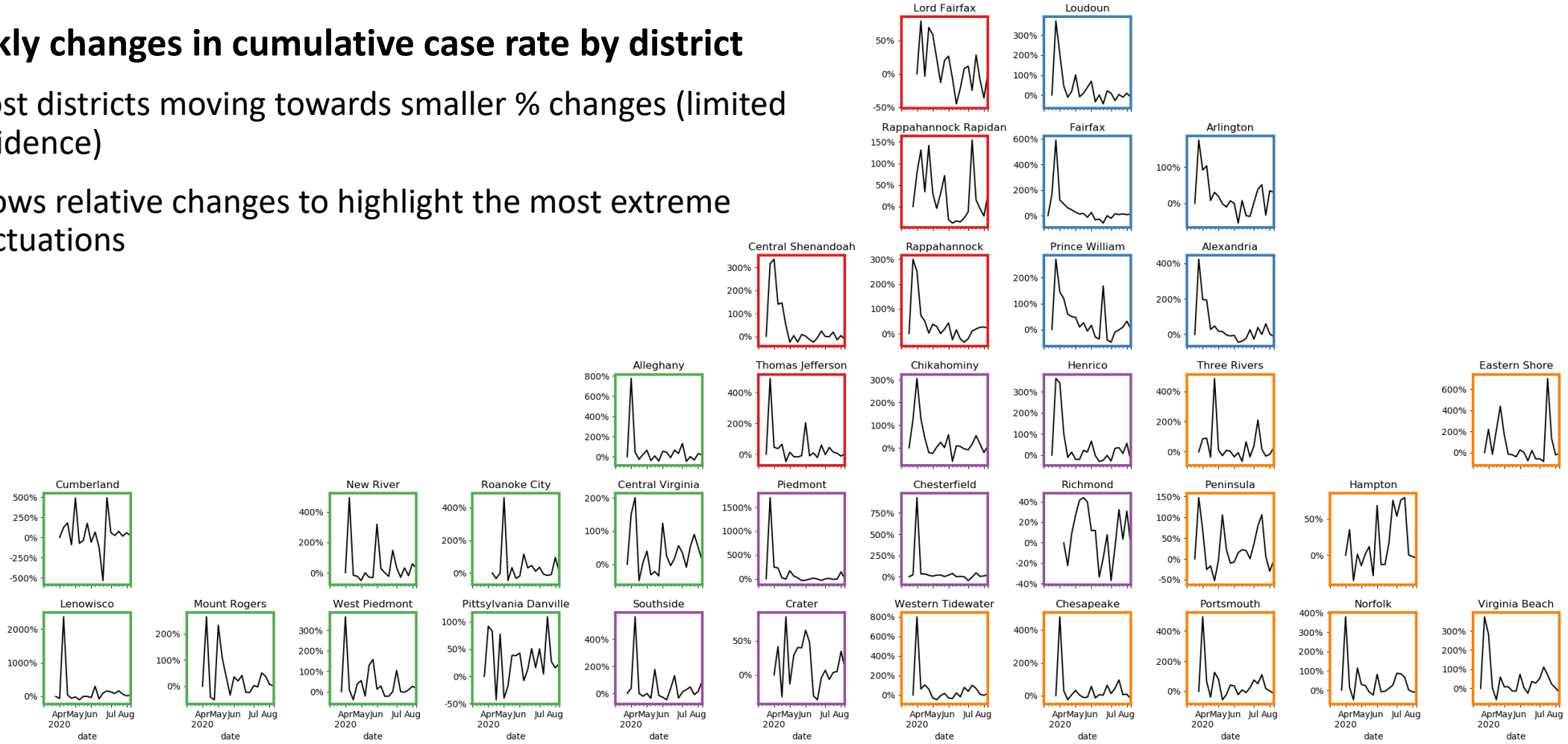
Percent Change of Case Rate by VDH District

Weekly changes in cumulative case rate by district

- Most districts moving towards smaller % changes (limited incidence)
- Shows relative changes to highlight the most extreme fluctuations



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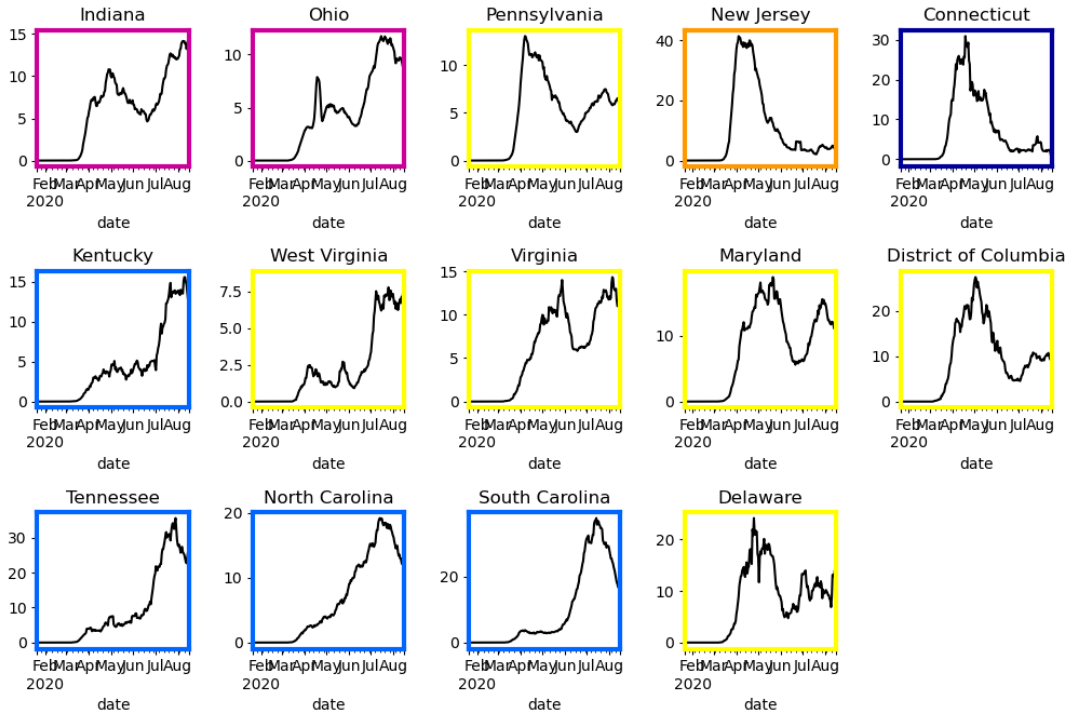
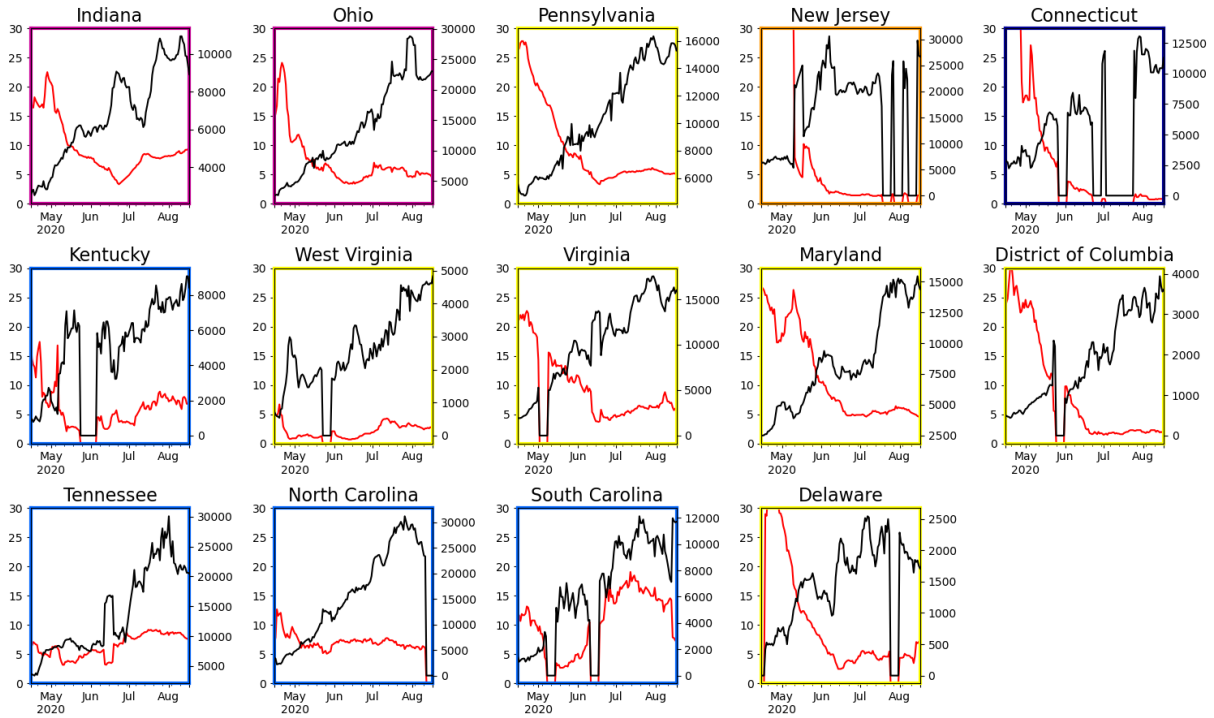
Other State Comparisons

Case Rate per 100K population



- Most states experiencing declines or plateaus in last couple weeks
- Virginia showing signs of plateauing

Tests per Day and Test Positivity

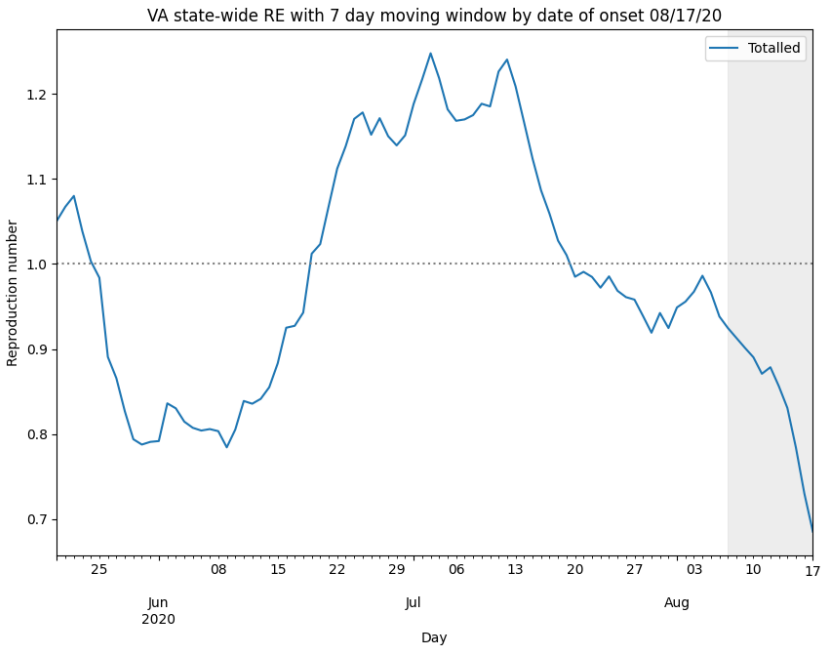


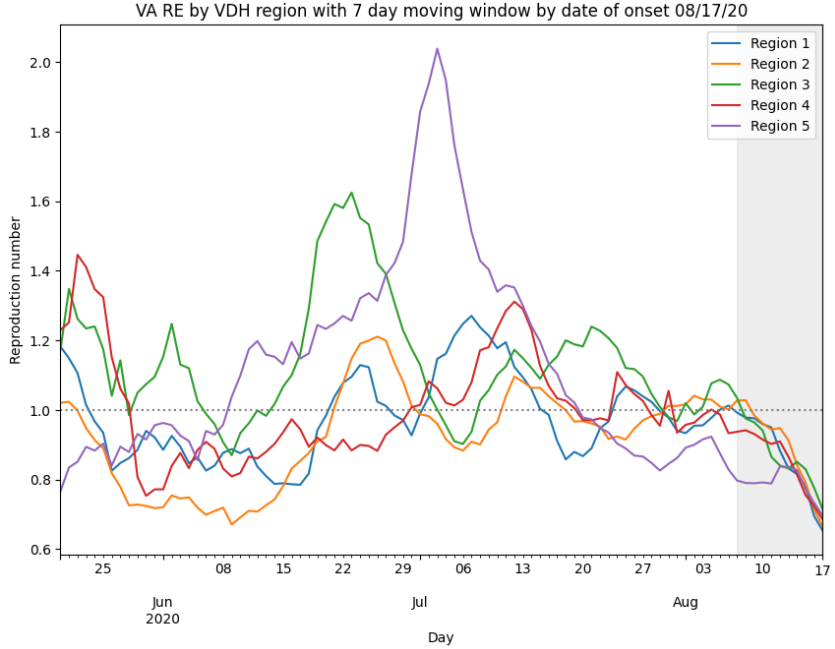
- Good signs as test positivity shows recent decline in most states
- Testing volumes plateau, potentially due to long turnaround times and individuals deciding to not seek a test

Estimating Daily Reproductive Number

August 8th Estimates

Region	Current R_e	Diff Last Week
State-wide	0.931	0.014
Central	0.942	0.005
Eastern	0.790	-0.087
Far SW	0.850	-0.289
Near SW	1.042	0.134
Northern	1.019	0.034
Northwest	0.978	0.215





Methodology

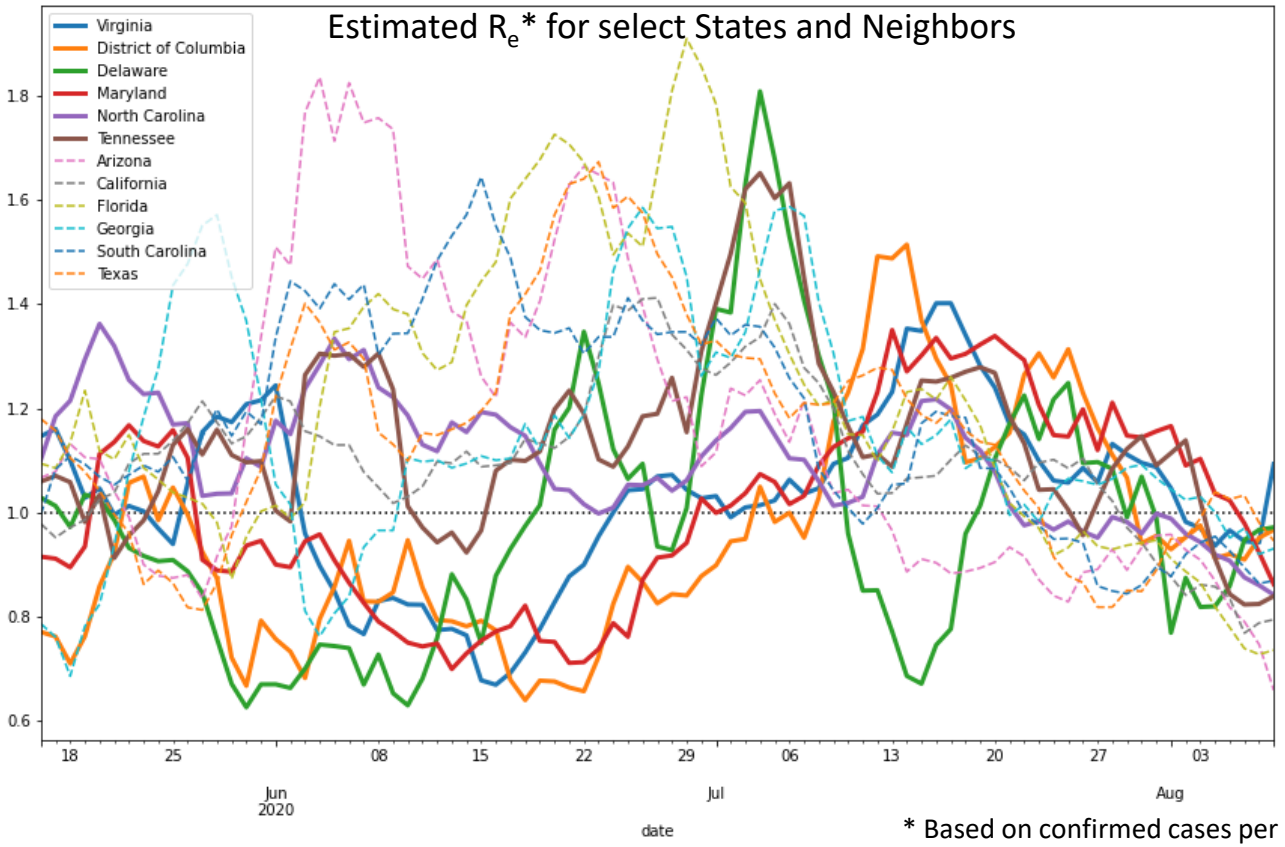
- Wallinga-Teunis method (EpiEstim[1]) for cases by date of onset
- Serial interval: 6 days (2 day std dev)
- Recent estimates may be unstable due to backfill

1. Anne Cori, Neil M. Ferguson, Christophe Fraser, Simon Cauchemez. A New Framework and Software to Estimate Time-Varying Reproduction Numbers During Epidemics. American Journal of Epidemiology, Volume 178, Issue 9, 1 November 2013, Pages 1505–1512, https://doi.org/10.1093/aje/kwt133

Other State Comparisons

Reproductive Number (R_e) has downward trend across hotspots and Virginia's neighbors

- Most of the national hotspots such as AZ, CA, TX, FL are now below 1
- Virginia and neighboring states are mostly at and below 1



VA and neighbors continued decline

* Based on confirmed cases per day

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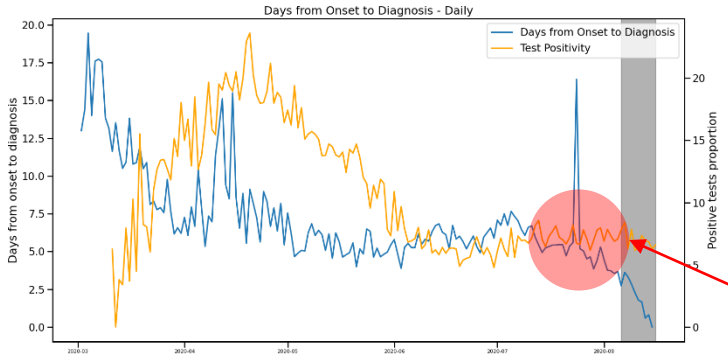
Changes in Case Detection

Days to Diagnosis dropped but rebounding

- Mid March to Late April = 8.1 days
- Late April to Late May = 5.7 days (30% lower)
- Late May to Late June = 5.6 days (31% lower)
- Early July to early Aug = 6.0 days (26% lower)

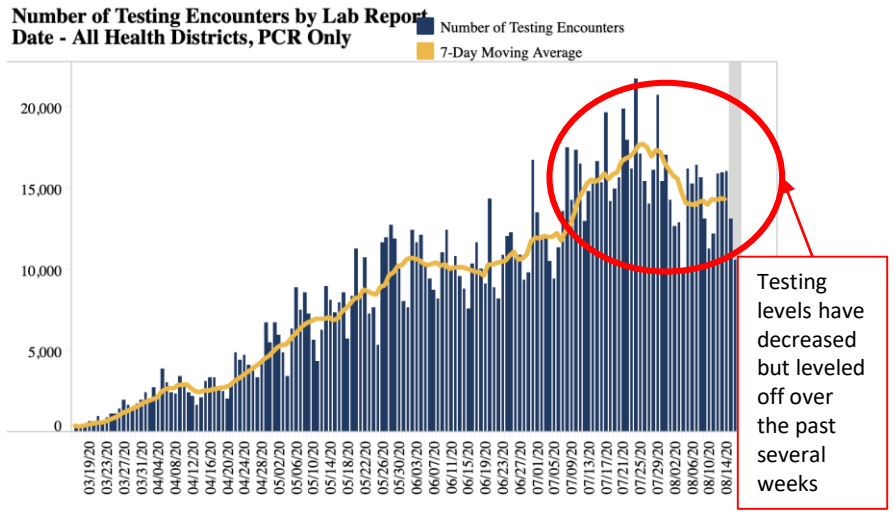
Rising level during weeks of test positivity rise

Test positivity vs. Onset to Diagnosis



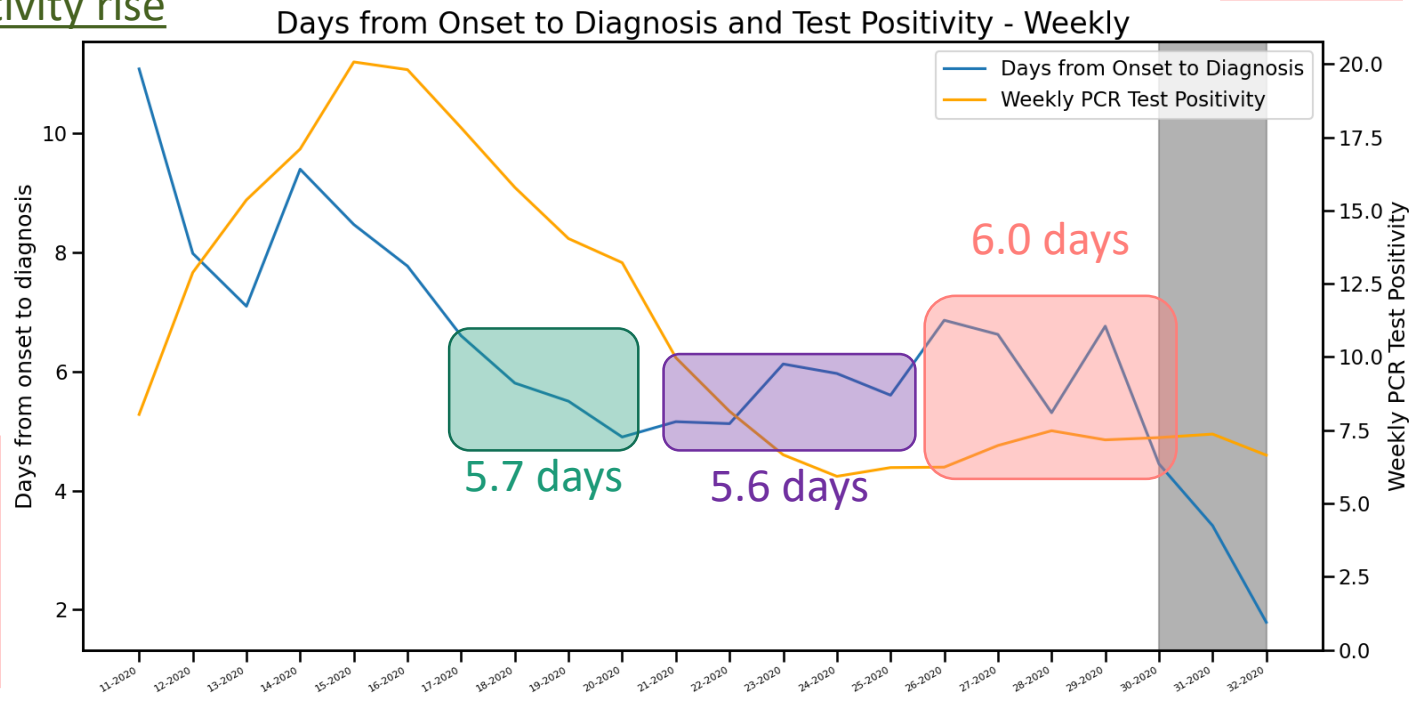
Steady plateau has been maintained for past several weeks

Testing Encounters and test positivity have steadied and increased

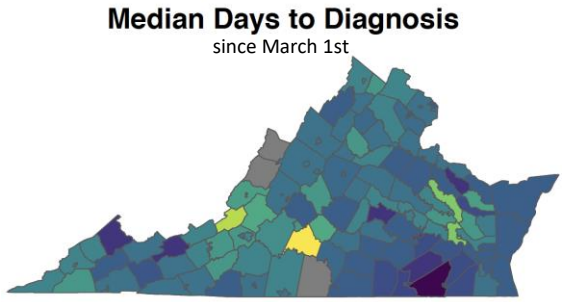


Testing levels have decreased but leveled off over the past several weeks

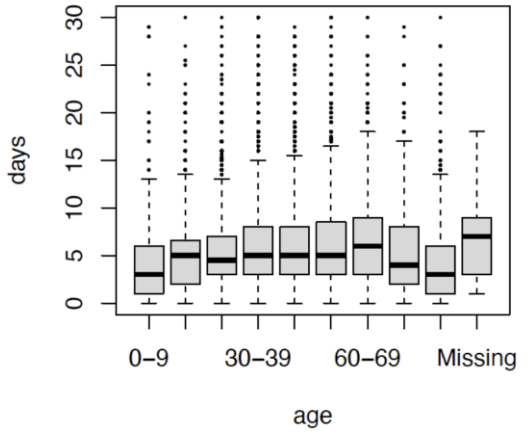
Accessed 8pm August 18, 2020
https://www.vdh.virginia.gov/coronavirus/



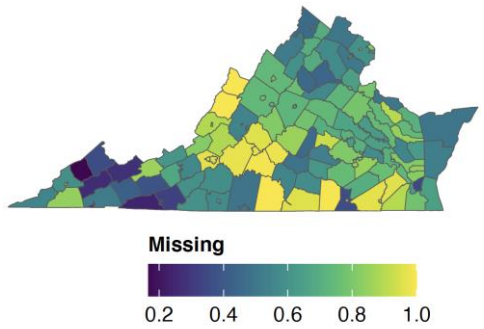
Changes in Case Detection – By District/Age



Slight variations by age group
(0-9, 70-79 and 80-89 have lower medians)
No significant variation by severity (hosp./ICU)



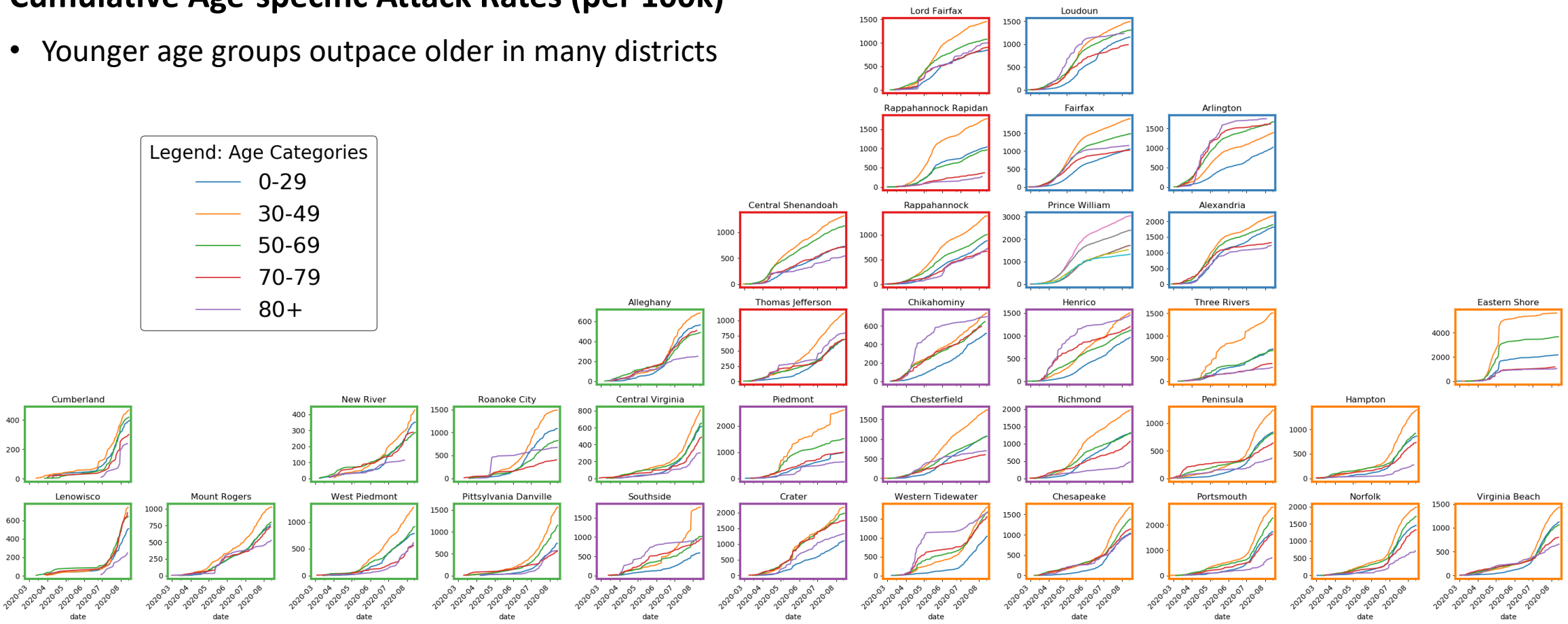
Only ~35% records have entries



Age-Specific Attack Rates (per 100K)

Cumulative Age-specific Attack Rates (per 100k)

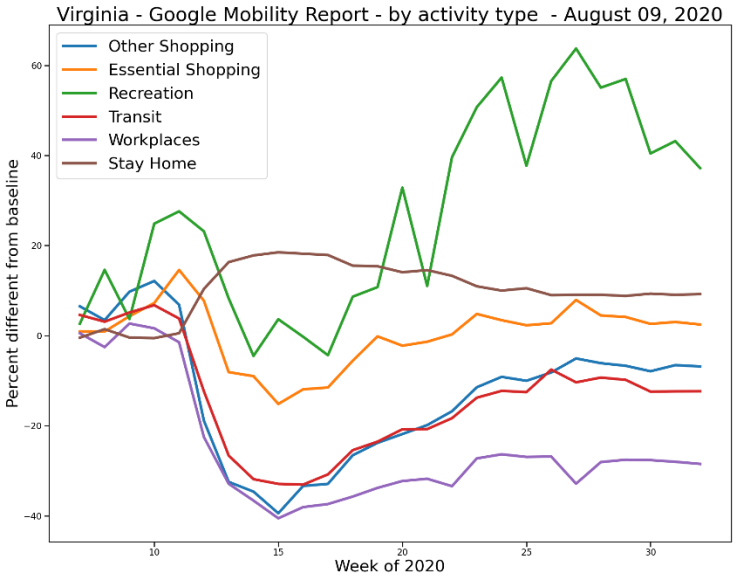
- Younger age groups outpace older in many districts

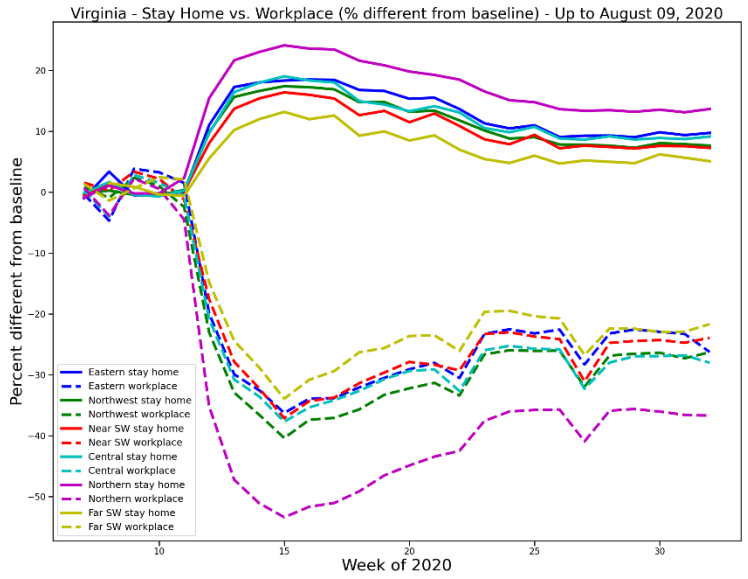


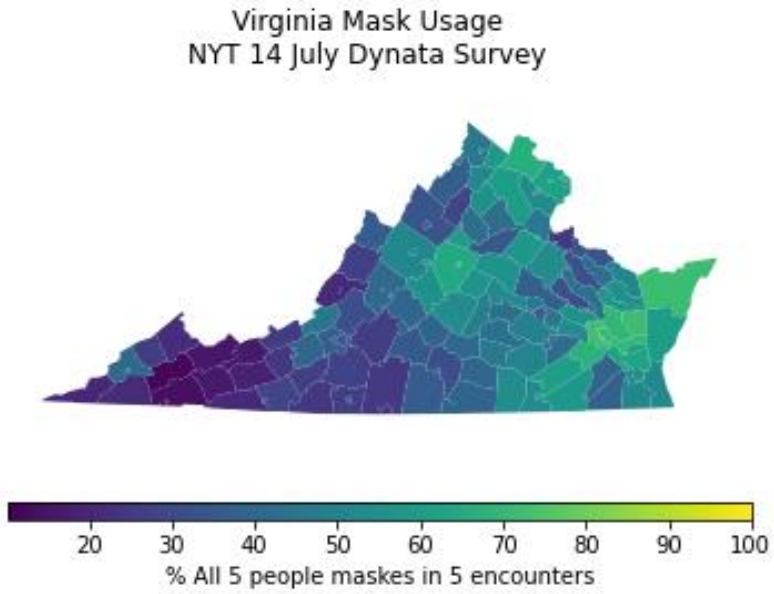
Estimating Effects of Social Distancing

Google Mobility data shows continued slow rebound (as of July 26th)
https://www.google.com/covid19/mobility/

- Continued slow reduction of those staying at home. Workplace levels remain low.
  - Urban/Rural variations in levels (e.g., Northern vs Far SW)
- Essential shopping back to baseline. Other shopping/transit trending towards baseline.
- Parks and recreation significantly higher than baseline (seasonal effects).
- Masks usage not evenly distributed, higher in Northern central, lower Southwest and Richmond area







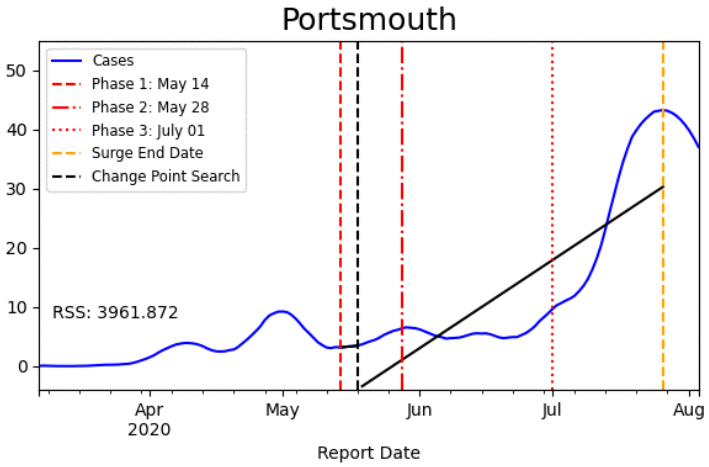
Surges Still Significant but Slowing

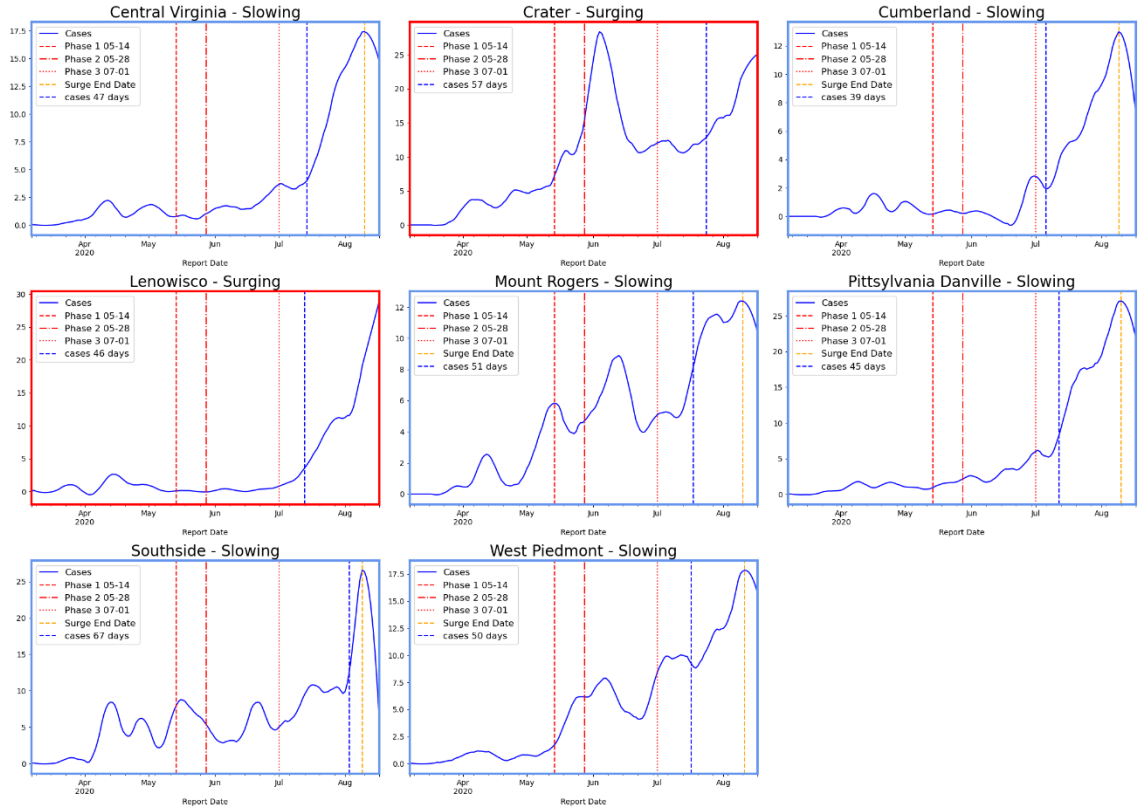
Fading Resurgence: Recent surges now decreasing

- Most districts have slowed and stated to decline, however, some continue to have sustained rapid growth

Surge Detection:

- Using “hockey stick” fit to assess timing of surge
- **Surging**: Best fits with slope greater than 2.5 cases / 100K
- **Slowing**: Surge with a peak in last 10 days
- **Ended**: Surge has peaked more than 10 days ago without rebound





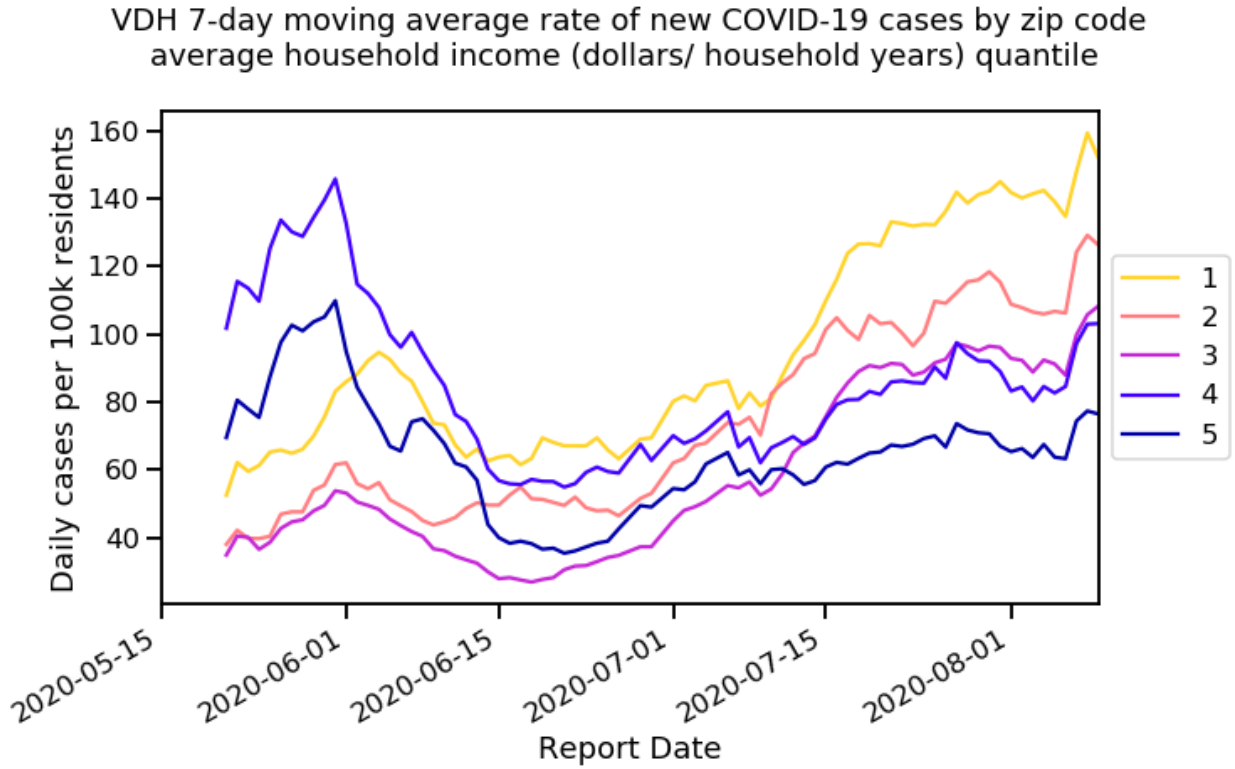
8 districts being tracked (compared to 15 last week)

Most are slowing initial plateaus or declines

In: Cumberland, Mount Rogers, Crater

Out: Virginia Beach, Alleghany, Roanoke City, Peninsula, Chesapeake, Norfolk, Three Rivers, Western Tidewater, Portsmouth, Hampton, Piedmont

Impact across Density and Income



Lower 20% income zip codes now reporting highest case rates

Can see the evolution from denser and wealthier zip codes to poorer and less dense zip codes

Model Update – Adaptive Fitting

Adaptive Fitting Approach

Each county fit precisely, with recent trends used for future projection

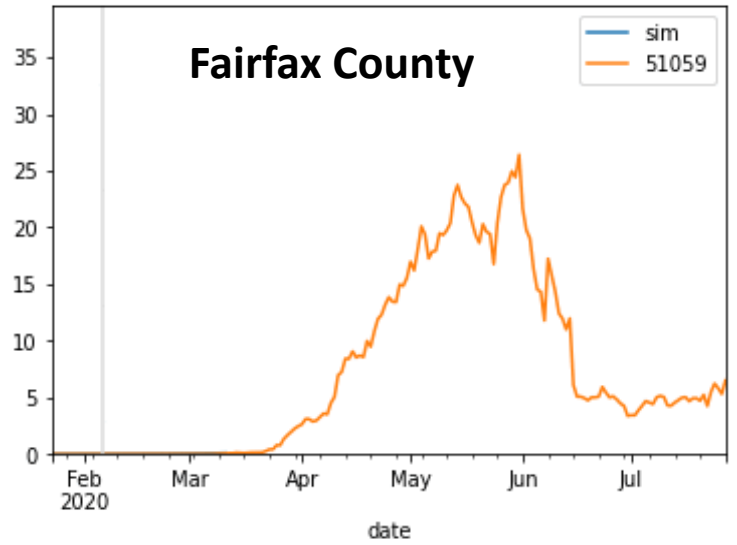
- Allows history to be precisely captured, and used to guide bounds on projections

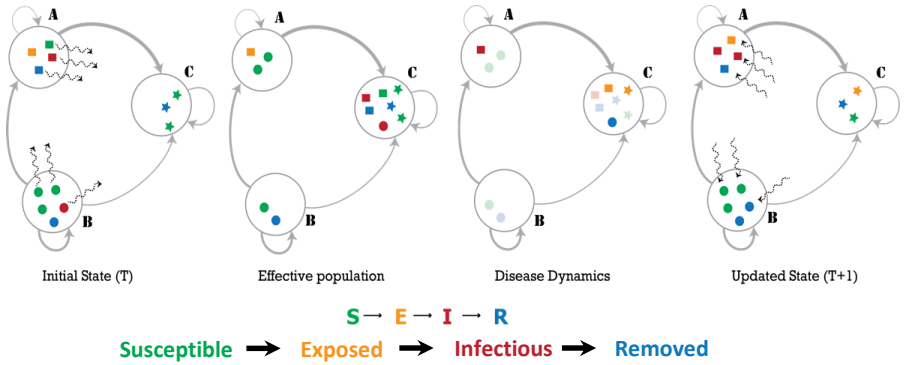
Model: An alternative use of the same meta-population model, PatchSim

- Allows for future "what-if" Scenarios to be layered on top of calibrated model
- Eliminates connectivity between patches, to allow calibration to capture the increasingly unsynchronized epidemic

External Seeding: Steady low-level importation

- Widespread pandemic eliminates sensitivity to initial conditions
- Uses steady 1 case per 10M population per day external seeding





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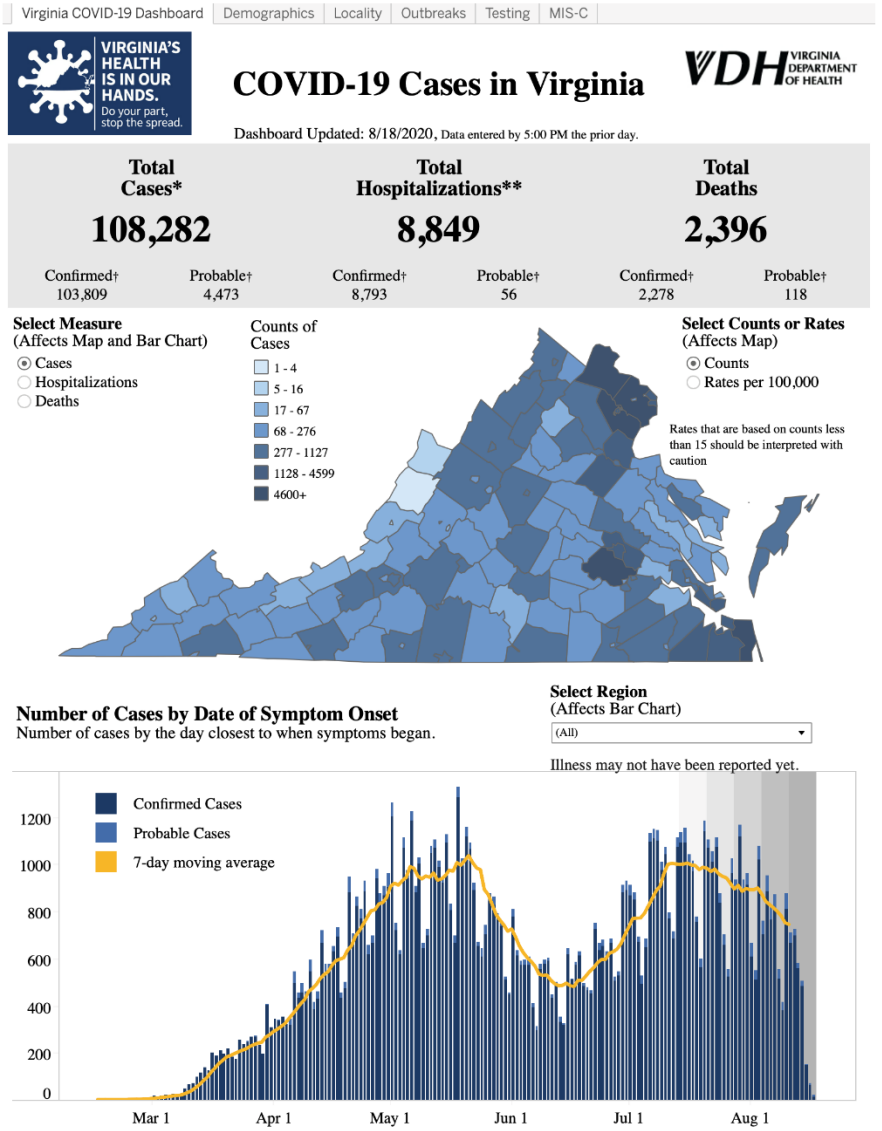
Calibration Approach

- **Data:**
  - County level case counts by date of onset (from VDH)
  - Confirmed cases for model fitting
- **Calibration:** fit model to observed data
  - Tune transmissibility across ranges of:
    - Duration of incubation (5-9 days), infectiousness (3-7 days)
    - Undocumented case rate (2x to 15x)
    - Detection delay: exposure to confirmation (4-12 days)
  - Approach captures uncertainty, but allows model to precisely track the full trajectory of the outbreak
- **Project:** future cases and outcomes using the most recent parameters with constraints learned from the history of the fit parameters
  - Last 14 day window used, informed by variances in the previous 4 weeks



Accessed 8pm August 18, 2020
https://www.vdh.virginia.gov/coronavirus/

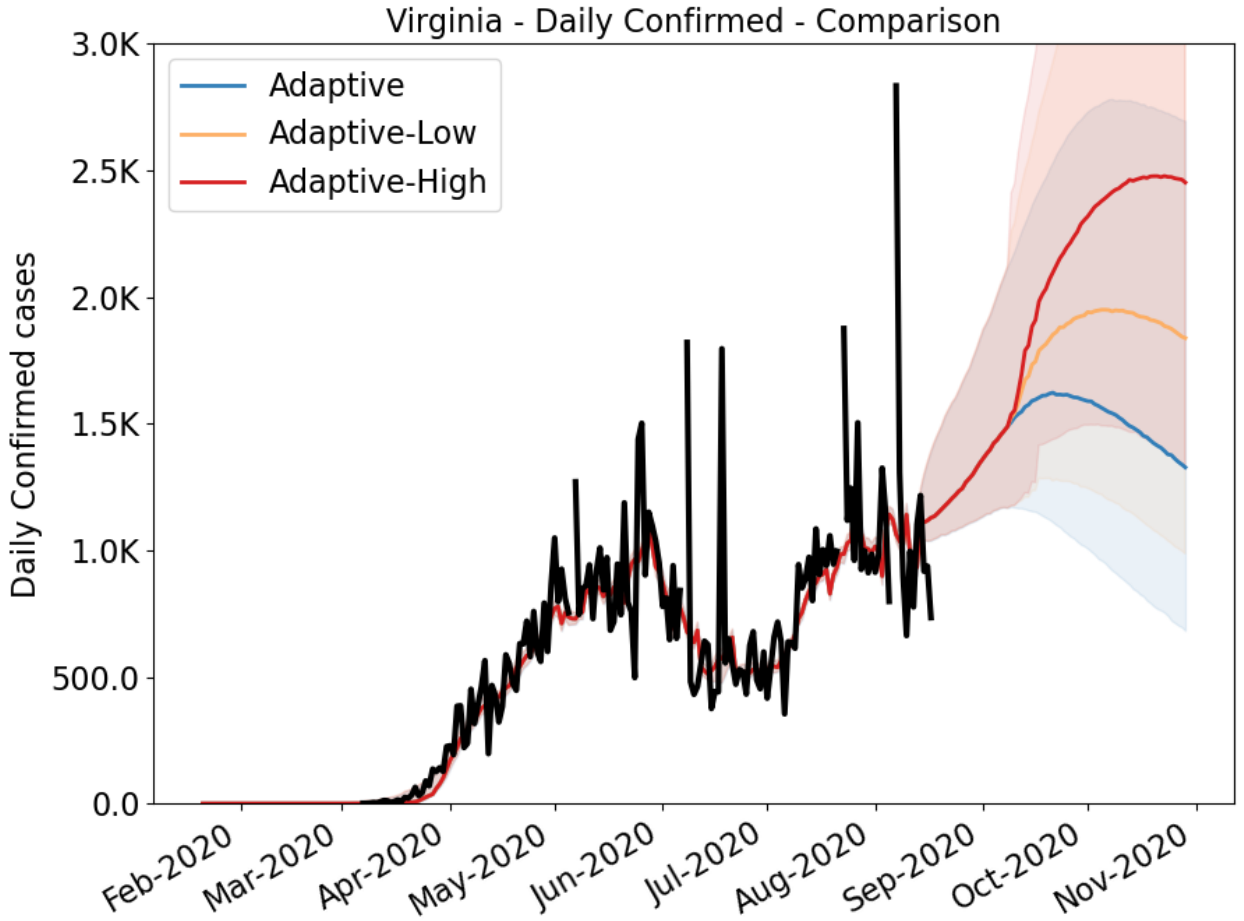
Scenarios – Seasonal Effects

- Societal changes in the coming weeks may lead to an increase in transmission rates
  - Start of in-person school
  - Changes to workplace attendance
  - Seasonal impact of weather patterns
- Three scenarios provided to capture possible trajectories related to these changes starting following Labor day, Sept 7th, 2020
  - Adaptive: No change from base projection
  - Adaptive-Low: 10% increase in transmission starting Sept 8th, 2020
  - Adaptive-High: 20% increase in transmission starting Sept 8th, 2020
  - Preliminary analyses of counties in Georgia that started in-person schools in early August indicate an initial 10% increase in transmission compared to those counties not yet started

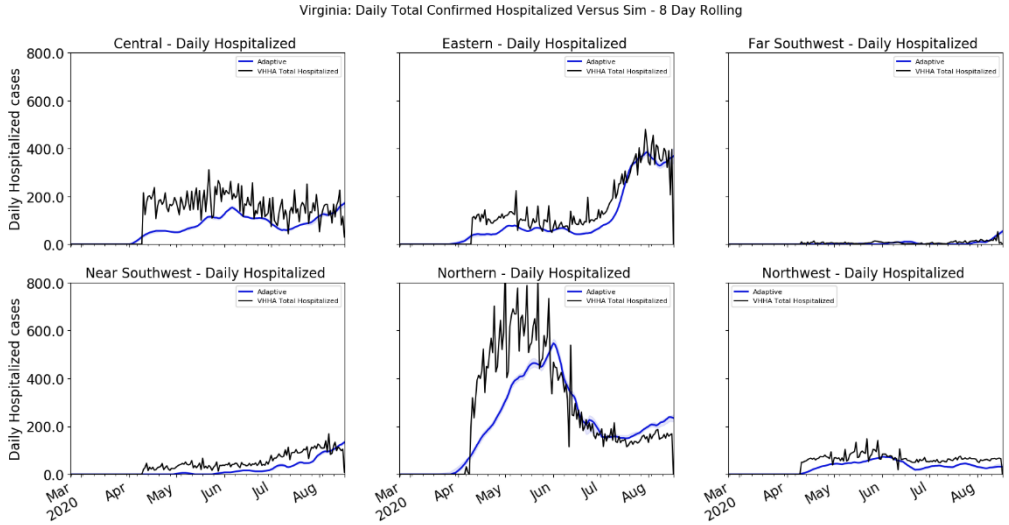
Model Results

Outcome Projections

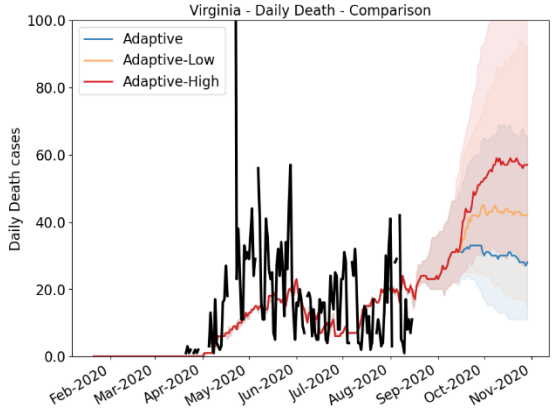
Confirmed cases



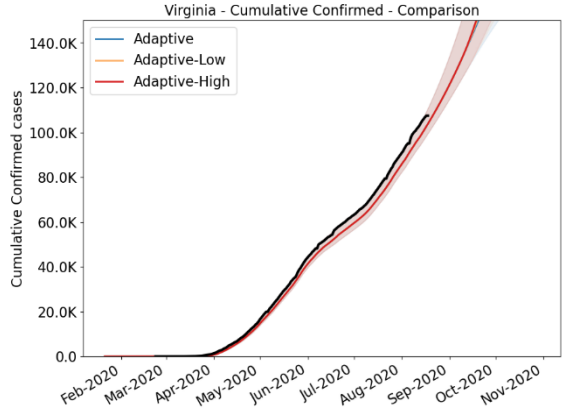
Estimated Hospital Occupancy



Daily Deaths



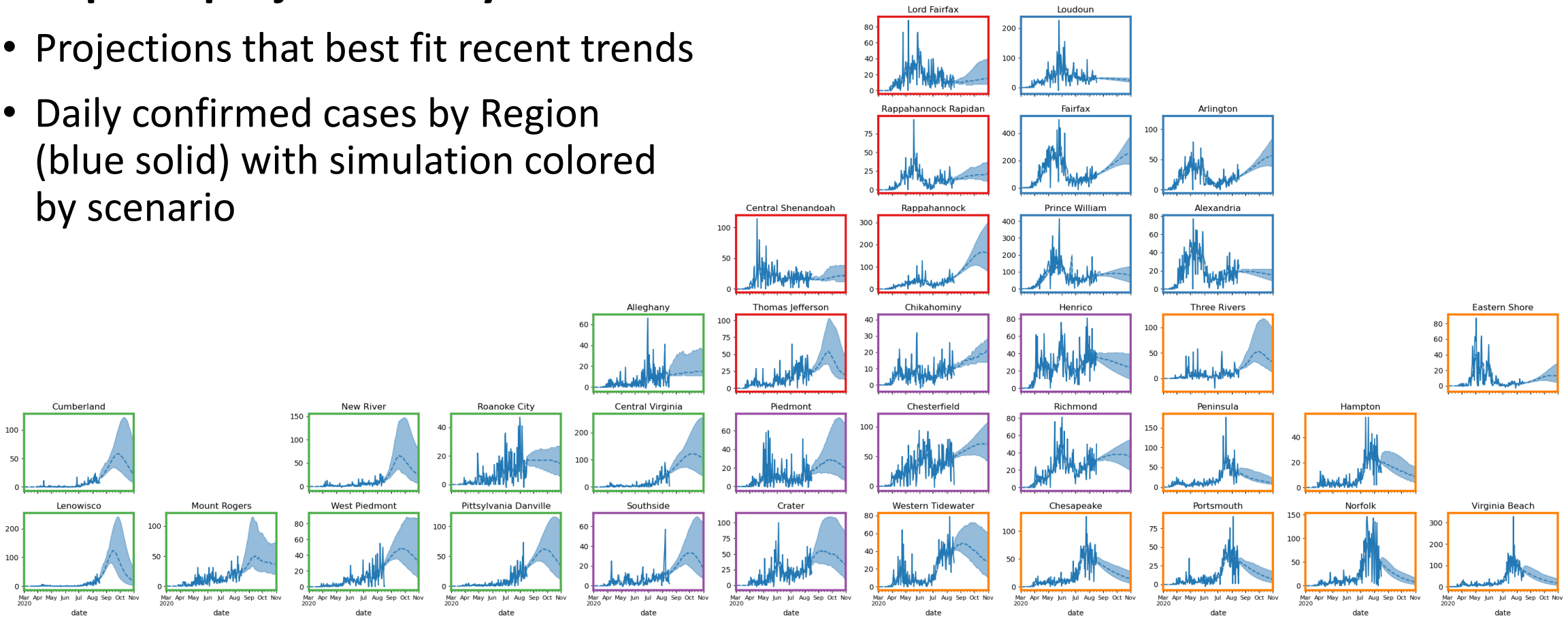
Cumulative Confirmed cases



District Level Projections: Adaptive

Adaptive projections by District

- Projections that best fit recent trends
- Daily confirmed cases by Region (blue solid) with simulation colored by scenario



District Level Projections: Adaptive-Low

Adaptive projections by District

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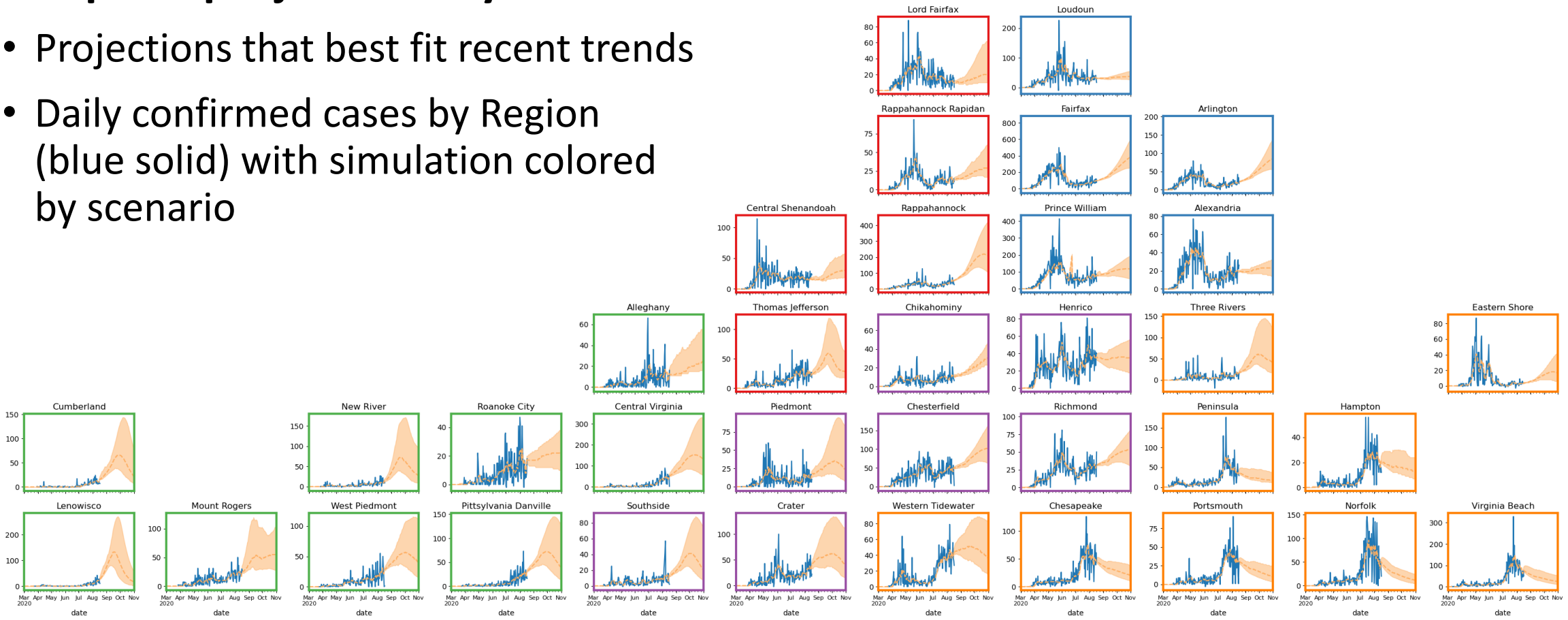

District Level Projections: Adaptive-High

Adaptive projections by District

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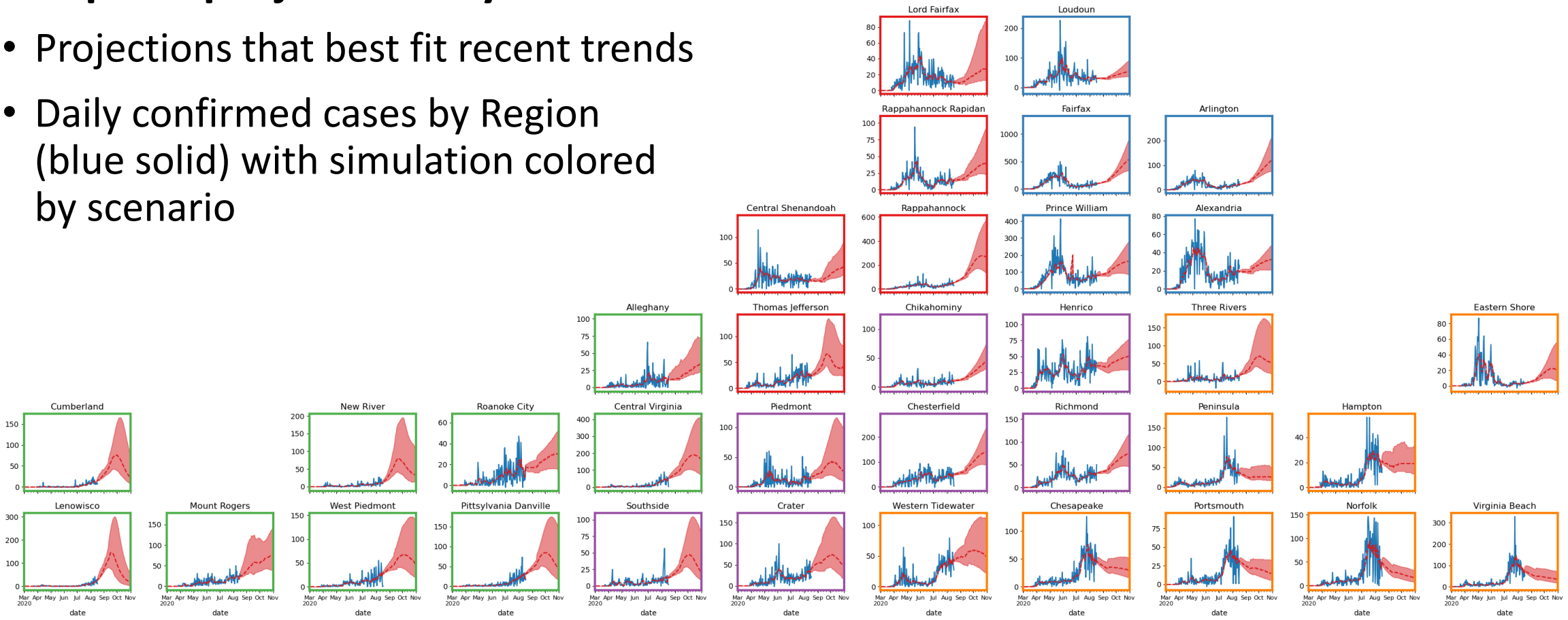
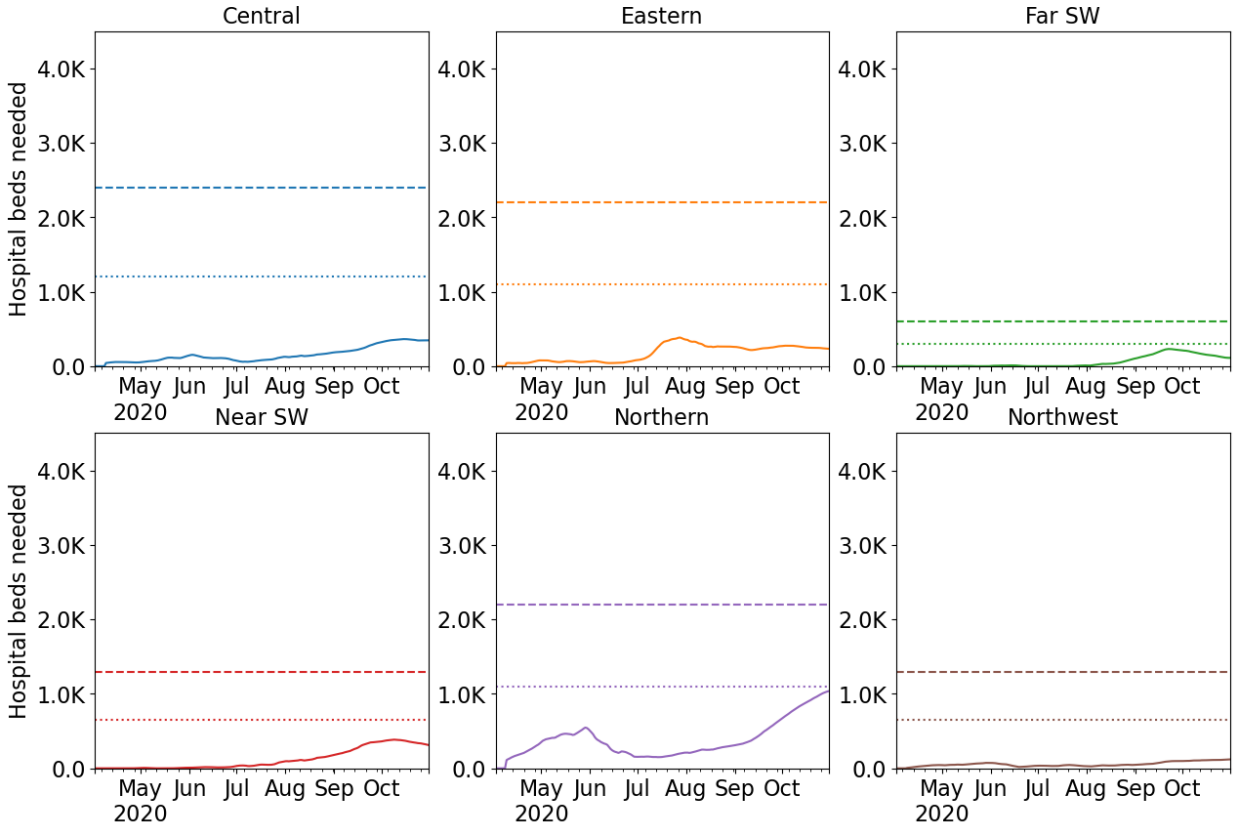


Hospital Demand and Capacity by Region

Capacities by Region – Adaptive-High

COVID-19 capacity ranges from 80% (dots) to 120% (dash) of total beds



Week Ending	Adaptive	Adaptive-High
8/16/20	7,163	7,163
8/23/20	7,972	7,972
8/30/20	8,638	8,638
9/6/20	9,527	9,527
9/13/20	10,416	10,558
9/20/20	11,082	13,074
9/27/20	11,306	14,841
10/4/20	11,180	15,950
10/11/20	10,882	16,728
10/18/20	10,454	17,171
10/25/20	9,960	17,320
11/1/20	9,444	17,241

Based on Adaptive-High scenario

- No regions forecast to exceed capacity
- Northern approaching capacity at the beginning of November

* Assumes average length of stay of 8 days

Key Takeaways

Projecting future cases precisely is impossible and unnecessary.
Even without perfect projections, we can confidently draw conclusions:

- **Surges are ending and slowing though incidence is high**
- Mixed trends across the commonwealth: surges, steady growth, slowed surges, and declines
- Projections show increasing incidence in short-term
- Recent model updates:
  - Adaptive Fitting projection, projection selection phased out
  - Seasonal effects scenarios for planning for end of summer changes
  - Extend projection horizon to Nov 1
- The situation is changing rapidly. Models will be updated regularly.

References

Venkatramanan, S., et al. "Optimizing spatial allocation of seasonal influenza vaccine under temporal constraints." *PLoS computational biology* 15.9 (2019): e1007111.

Arindam Fadikar, Dave Higdon, Jiangzhuo Chen, Bryan Lewis, Srinivasan Venkatramanan, and Madhav Marathe. Calibrating a stochastic, agent-based model using quantile-based emulation. SIAM/ASA Journal on Uncertainty Quantification, 6(4):1685–1706, 2018.

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Google. COVID-19 community mobility reports. https://www.google.com/covid19/mobility/

Cuebiq: COVID-19 Mobility insights. https://www.cuebiq.com/visitation-insights-covid19/

Biocomplexity page for data and other resources related to COVID-19: https://covid19.biocomplexity.virginia.edu/

Questions?

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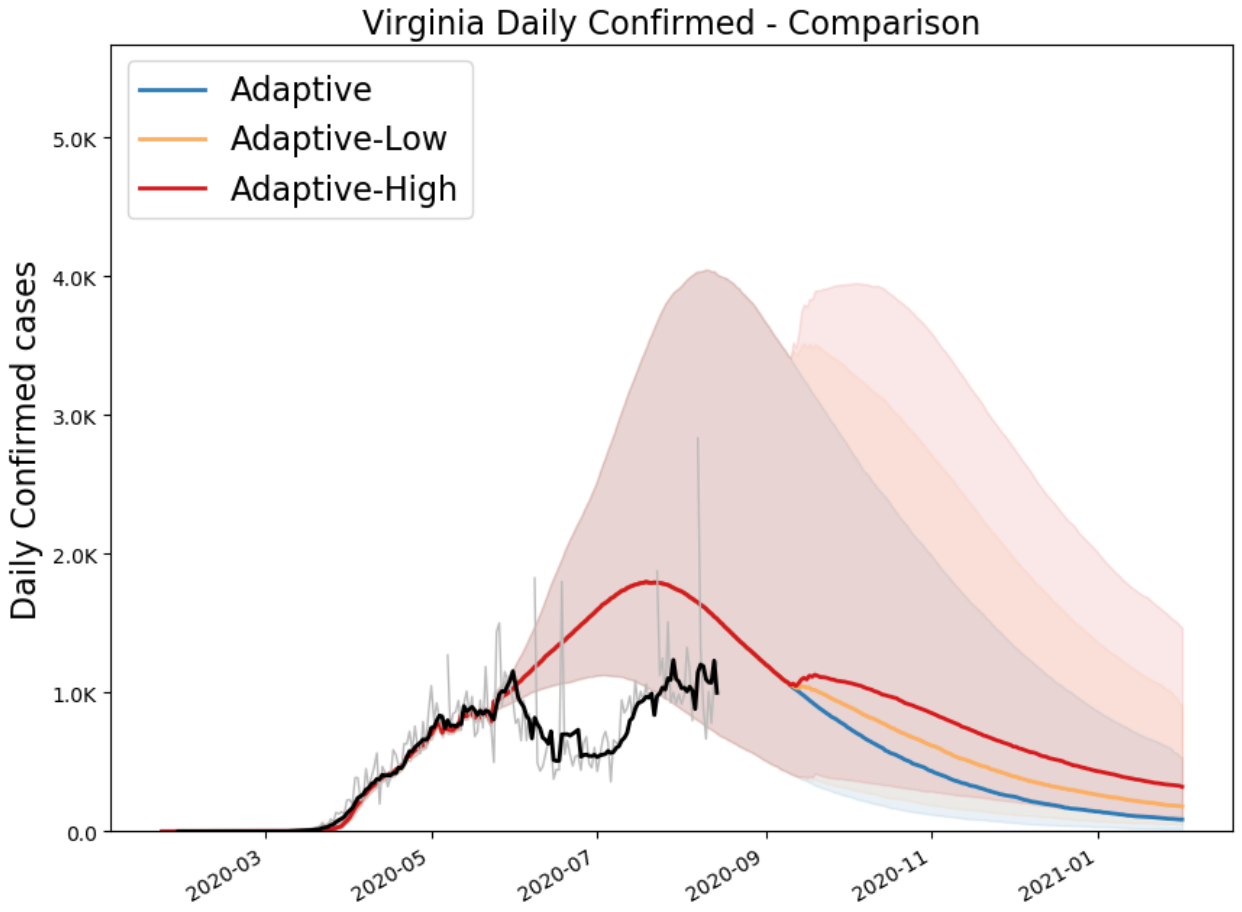
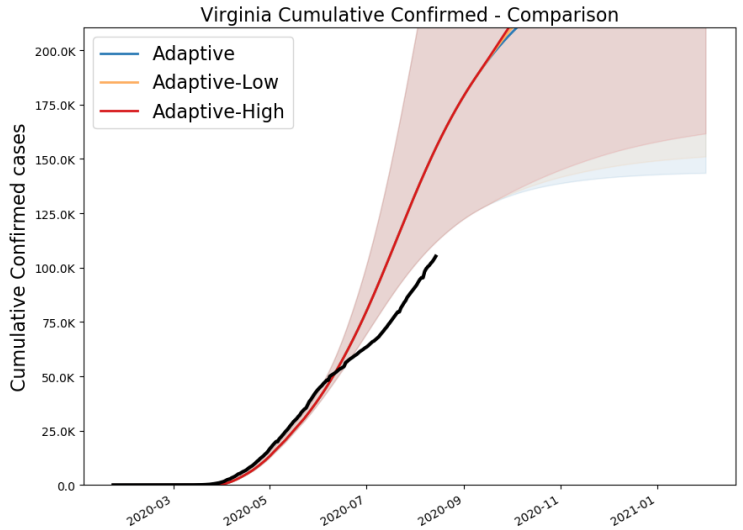
Supplemental Slides

Counter-factual Analysis



“What If” the whole Summer was like late Spring?

- Scenario where the trends present up to Memorial Day week had persisted throughout the summer
- Over 58K cases averted



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Recent Parameter Validation

New York State announced sero-prevalence survey results on May 2nd

- 15,000 antibody tests conducted randomly through the state at grocery stores
- **Total Attack Rate**: 12.3%

Estimation of undetected infections

- Total infections in NY = 2.46M, total of 300K confirmed cases
- Confirmed case detection = 12% of infections (close to 15% used in model)

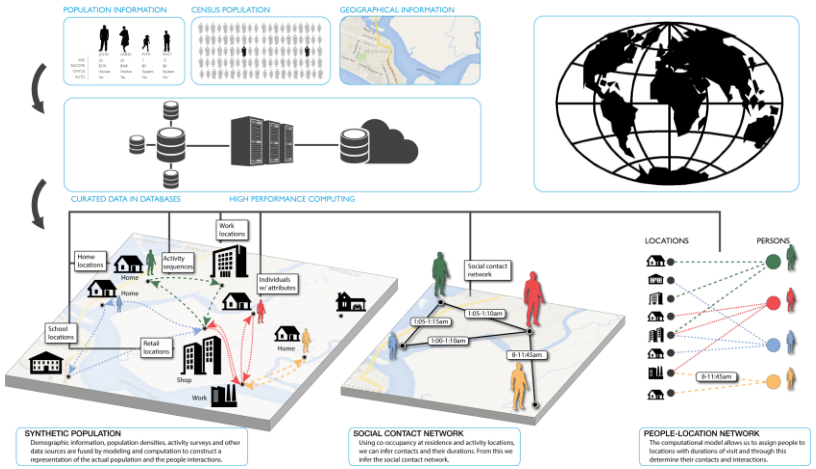
Estimation of hospitalizations from infections

- Total infections in NY = 2.46M, total of 66K hospitalizations
- Hospitalizations = 2.7% of infections (close to 2.25% used in model)

Agent-based Model (ABM)

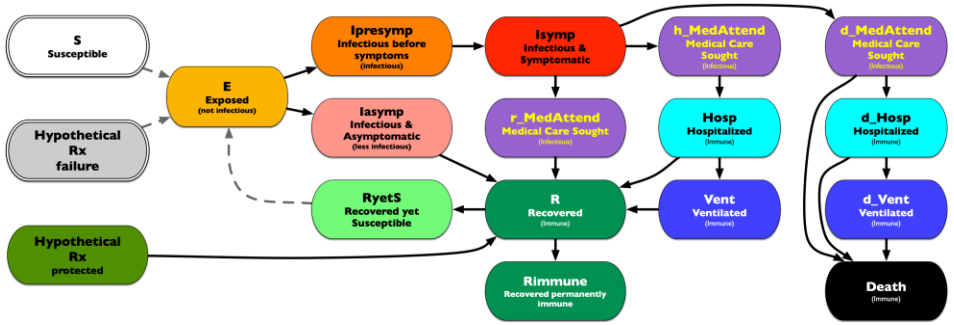
EpiHiper: Distributed network-based stochastic disease transmission simulations

- Assess the impact on transmission under different conditions
- Assess the impacts of contact tracing



Synthetic Population

- Census derived age and household structure
- Time-Use survey driven activities at appropriate locations



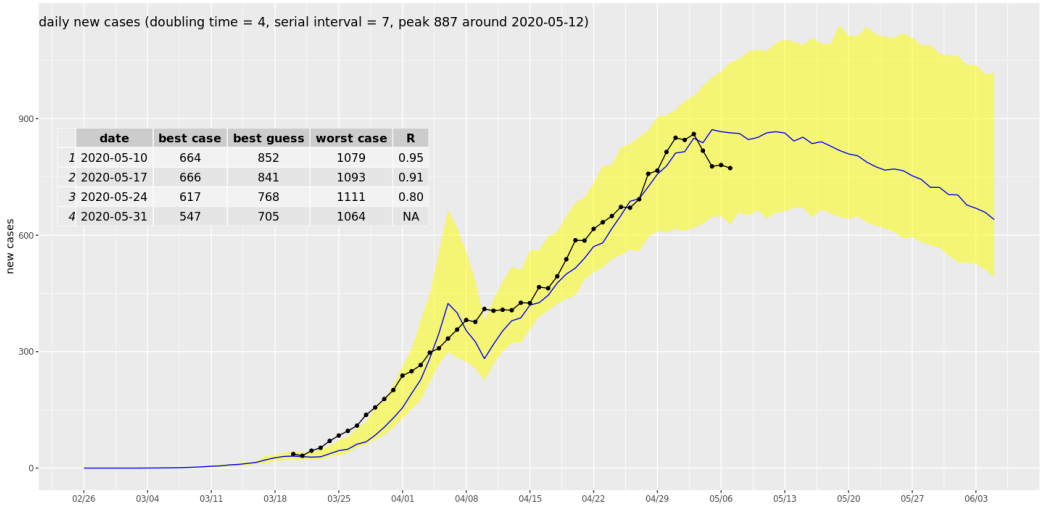
Detailed Disease Course of COVID-19

- Literature based probabilities of outcomes with appropriate delays
- Varying levels of infectiousness
- Hypothetical treatments for future developments

ABM Social Distancing Rebound Study Design

Study of ”Stay Home” policy adherence

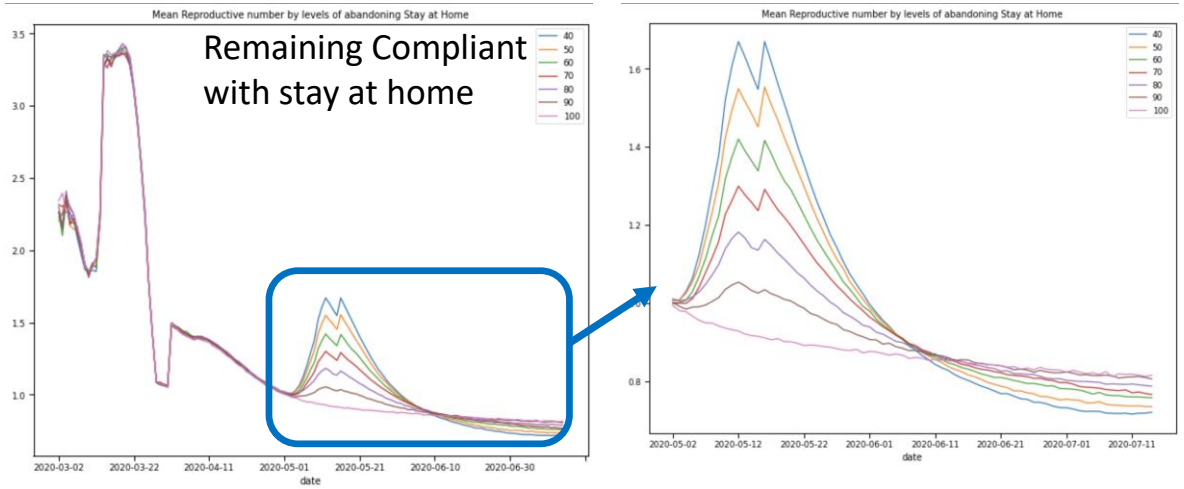
- Calibration to current state in epidemic
- Implement “release” of different proportions of people from ”staying at home”



	date	best case	best guess	worst case	R
1	2020-05-10	664	852	1079	0.95
2	2020-05-17	666	841	1093	0.91
3	2020-05-24	617	768	1111	0.80
4	2020-05-31	547	705	1064	NA

Calibration to Current State

- Adjust transmission and adherence to current policies to current observations
- For Virginia, with same seeding approach as PatchSim

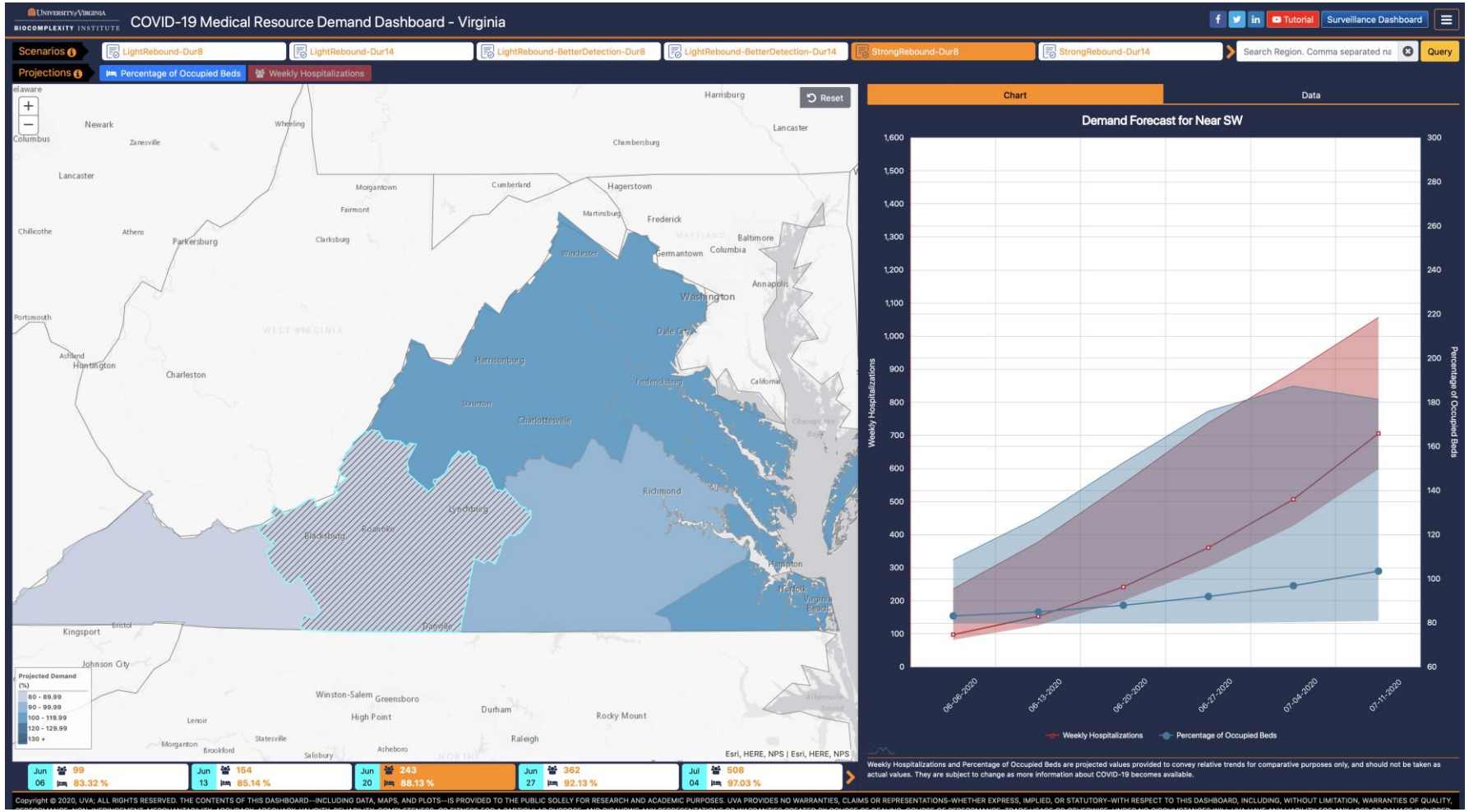


Impacts on Reproductive number with release

- After release, spike in transmission driven by additional interactions at work, retail, and other
- At 25% release (70-80% remain compliant)
- Translates to 15% increase in transmission, which represents a 1/6th return to pre-pandemic levels

Medical Resource Demand Dashboard

https://nssac.bii.virginia.edu/covid-19/vmrddash/



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